Building With Straw Bales
Lecture notes by
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For updated versions periodically check www.homegrownhome.co.uk

There are numerous types of straw, bales and construction techniques. In these notes I aim to introduce as many as possible, discuss some of their relative advantages and disadvantages and provide links for further research.

The possibilities with straw are endless!

Contents

1. Frequently asked questions

What is the fire risk with a straw bale building?

A bale of straw is often compared to a telephone directory. Loose straw or a single page of the directory will readily burn. However, it is very difficult to set fire to the dense bale or the whole directory as there is very little oxygen in there. Add to that 25 mm of clay or lime render and you have a wall assembly that will easily withstand more than two hours in a fire test. There have been many tests carried out around the world to confirm this (see recommended reading - Bruce King).

Are rats and mice a problem in a straw bale building?

Some say that rodents will not live in straw because there is no food supply but this is not true. As any farmer will tell you, a straw stack is a very popular home for rats and mice. Luckily though, there is a big difference between a farmer's straw stack and a straw bale building; in a well designed building the straw is completely sealed on all sides to prevent rodent entry and the bales are dense and carefully stacked together with no gaps whatsoever.

There is a further advantage if the bales are under compression as in a load bearing building – the bales are so tightly pressed together that the rats and mice would be unlikely to live there.

Our building bales for the cottage were riddled with mice in the over winter store. Out of 700 bales we struggled to find the 300 we needed that had not been chewed through. However, it was very reassuring to find that one part of the stack where some large, heavy big round bales where placed on the top there were no mice taking up residence!

Can rain damage a straw bale building?

Water is the main enemy of all natural building materials. Prolonged exposure to water would result in decay. However, with appropriate design, attention to detail in construction and timely repair in use straw bales, timber and hemp can last a very long time.

Design techniques include a large roof overhang or porch, a breathable render or a ventilated rain screen and raised foundations or wall base. These simple measures were widely used in the old buildings.

How long should a straw bale building last?

Straw bale buildings are relatively new in the UK but we have been using straw in cob buildings and in plaster for centuries. As described above, if it is kept dry it can last forever.

The straw bale house in France built in 1921 is the oldest European example but there are several houses in the USA which are over one hundred years old.

2. About straw and bales

2.1 Straw

Straw is the dead, dried stem of cereals. It is left over after the grain is removed in harvesting process. It is mostly used for animal feed and bedding, eventually finding its way back to the land in the form of nutrient rich farmyard manure. Sometimes it is chopped directly behind the harvester and incorporated back into the soil by ploughing. Straw is increasingly being burned for heat and power, encouraged by Government subsidy. My recent report on why this is not a good idea can be downloaded at http://www.nuffieldinternational.org/reports/report.php

In the UK we mainly have wheat straw. In 2009 we grew approximately 1.6 million hectares of wheat, the straw yield from which could vary from 2.5 to 5 tonnes per hectare. We have lesser quantities of barley and oat straw and also the straw from the oilseed rape crop.

My preference for building is wheat straw. It feels stronger and the straws hold their shape well (trapping more insulating still air within). Barley is a softer straw, it seems to flatten more easily, and the bales contain little itchy “horns” that can be a nuisance during building. Barley and oat straw is usually more expensive as it is a more palatable animal feed than wheat straw. Oil seed rape straw is very rough and spiky – not the nicest to work with if stacking and plastering by hand. I also feel that there is too much “untrapped” air in rape straw, which would compromise insulation values. I don’t have scientific proof, however!

All this said, every type of straw makes a more than adequate building material. Use what is locally available.

Straw for sale is usually not organically grown. The organic farmers don’t like to part with straw - it is a valuable source of nutrients in their farming system.

In the USA rice straw is the preferred material. It can take two years to decompose in the field so the farmers would rather have it baled out of the way and the builders like to use it. A building I visited in Nebraska used the baled dry stalks of the prairie grasses – it is best to use what is locally available. Normally we wouldn’t use baled grasses (commonly known as *hay*) because of higher nutrient levels.

The main criteria for good straw are that it should be clean and dry. The perfect scenario is a few days sunshine to dry the standing crop, more sunshine during harvest, a day or two for the straw to dry a little more in the swath and finally baling and leading into a shed on a lovely sunny day. Sometimes the British summer will oblige and the result will be bright yellow, fresh smelling bales of straw!

Length of straw can vary with the variety of cereal grown, the growing season, whether or not a chemical shortening was used, humidity levels at harvest, the type of combine harvester and type of baler. The main thing to watch for is that it is not too short – if lots of straw pulls out of the bale very easily, it is probably too short and unlikely to hold the plaster well.

2.2 Bales

There are many types of baling machine resulting in many shapes and sizes of bales. The most common found today in the UK are the large "Heston" bales. The largest measure 1.2m by 1.2m by 2.4m. Farmers prefer them because they can be baled and led away very quickly. Hauliers prefer them because they quickly and easily load on their lorries and trailers. There is a smaller, Mini Heston bale measuring 0.85m by 0.9m by 2.4m. It is possible to build with Hestons and Mini Hestons but lifting equipment is required.

Large round bales (usually 4 to 5 metres in diameter) are also popular on farms but are little use for building purposes.

The small bales that are most useful for building come in a variety of sizes; an example would be 0.45m by 0.35 x 1m. The bale chambers govern the width and depth of bales and can vary by 100mm or so according to the make and model of baler. The bale operator can set the length of bales. The life of a straw bale builder is much easier when the size of the bales is known at the design stage.

Most small bales have a cut side and a folded side. Balers tend to be trailed to the side of a tractor so that the operator can see the straw being fed into the machine. The bales are packed from the side. They have a *folded side* where the straw is pushed into the bale chamber and a denser *cut side* where the straw is trimmed to size by sharp knives.

A straw bale viewed from the cut side

A straw bale viewed from the folded side

The modern Massey Ferguson 1839, centre line baler, however trims the bales underneath so that both sides of the bale are folded.

Modern polypropylene baler twine is the best to use – preferably in a colour other than yellow, as this can be difficult to see among the straw. Most small bales in the UK have 2 strings. There is much reference in US books to 3 string bales but they are not common here.

Small baling machines are less popular these days but it is usually possible to find one or two local farmers or contractors still using them. Small bales are still used by horse owners or on small farms without facilities for large bales or the equipment needed to use them.

A Welger baler making small bales

In countries where baling machines are not available, it is possible to make a levered device from wood or metal to hand make bales. You can see a metal one being used in Pakistan by following this link http://www.paksbab.org/gallery/

My preference for the density of good building bales is 100-125 kg/m3. Firm and strong but not too dense that all the air (necessary for insulation) has been squeezed out of them. Some builders using the frame method (see below) prefer bales in the 80-100 kg/m3 range because they contain more air. (Note that air must be "still" to be insulating, air movement increases heat loss)

Harvest can be a very stressful time and farmers are much more concerned about the quality of the cereal than the quality of the straw bales. Some builders are tempted therefore, to re-bale. They gather the straw quickly into large bales at harvest and re-bale them into tight, smaller building bales later. There are several problems with this; more time and diesel is needed, there is a lot of dust and mess, the straw will have dried out and become more brittle in the big bale so re-baling would probably result in smaller straw length and less trapped air.

Storage
Having led the perfect building bales from the field, it is important to store them correctly – protected from rain and vermin such as rats and mice. Store on pallets

unless prepared to sacrifice the first course, which will inevitably wick moisture from the ground.

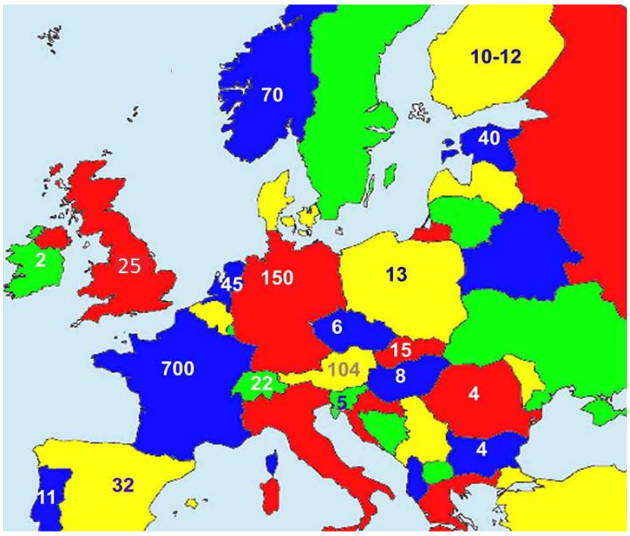
3. About building with straw

3.1 A brief history of straw bale building

Straw and other natural fibres were used in man's very early buildings. Bales, however, were first used in the USA in the late 1800's after the invention of the baling machine. European settlers on the Nebraskan Plains had no timber with which to build their homes so they stacked their bales for shelter. The oldest straw bale house still standing in Nebraska today was built in 1903.

In the 1940's a combination of war and the popularity of Portland cement led to the virtual extinction of straw bale building – until a revival by US green building pioneers in the 1970's.

Building with straw bales is also gaining popularity in mainland Europe. The oldest European straw bale house was built in France in 1921. The map below is a very approximate guide to the number of straw bale homes in Europe. We will see later the many other types of buildings that can be constructed with straw.



This is an approximate guide to the number of straw bale dwellings in Europe. It has been prepared by Professor Burkard Rueger of FASBA (the German Straw Bale Association www.fasba.de) from information gathered through the European Straw Bale Network www.strawbale-net.eu

3.2 Methods of Construction

Load bearing straw bale walls

This is the purest form of straw bale building. Stacked bales alone bear the weight of upper storeys and the roof, minimising the use of timber. The disadvantage in a wet climate is that the walls are built before the roof. Bales must be kept dry at all times so a daily, rigorous tarpaulin routine can become tiresome. However a temporary roof is possible on small projects or a final roof suspended above the bale walls can be engineered ready to lower into place on top of the bales.

Good bales are incredibly strong and easily able to carry roof loads. Bruce Kings book (see recommended reading) is a good reference for the many tests carried out around the world. The problem is that bales vary and for bigger projects especially, structural engineers can struggle to embrace such a variable material – currently straw bales don't come certificated!

My personal preference is for a load bearing design, especially where the roof is ready above the walls to be lowered into place on top of the final course of bales. After a few days, the weight of the roof settles all the bales into each other creating an integrated roof/wall system. Very satisfying when it works well!

Timber framed straw bale walls

The main advantage is that the frame can be erected and the roof put on before straw bales come to site, removing the pressure to build in dry conditions. Engineers are happy because they can feed the figures for the timber into their computer programs – sometimes completely ignoring the strength and racking benefits of the straw, which is a shame because in reality they contribute much to the structure.

Bales can be stacked between the frame, inside the frame or outside the frame, depending on preference. The frame can be made with any timber – perhaps oak, glulam or stripped round wood if it is to be seen, or rough sawn carcassing timber or OSB panels if it is embedded in the wall. Using reclaimed timber is possible but again not popular with engineers due to lack of certification.

From a construction point of view, the main difficulty with a frame comes with the last course of bales – getting a perfect fit can be tricky and time consuming.

Hybrid forms

A compromise can work well. Using small dimension timber to minimise its use whilst still providing additional support or a system to compress bales inside or outside a frame

Pre-fabricated straw bale panels

There is a great deal of development going on around the world with pre-fabricated panels. In the UK we have proprietary panels made by Modcell which have undergone research at The University of Bath
http://www.bath.ac.uk/features/balehaus/

In Canada, Chris Magwood is developing a system with students, which can be seen on You Tube - http://www.youtube.com/watch?v=q61og2ydZKc

These are both off site manufacture. At the European Straw Bale Gathering in Belgium in August 2009 some of the German contingent made straw bale panels *on* site. Wooden panels were filled with straw whilst laid on the ground then lifted up into place by crane or teleporter. Individual bales did not have to be lifted up, knocking them into the panels could be carried out more safely at ground level and there were savings on scaffolding costs too.

Steel frames
Where it is absolutely necessary to specify a steel frame, the bales should be stacked either inside or outside of it, preferably not between it. Metal is a cold material on which water vapour may condense therefore it should not be in the centre of a straw bale wall.

Bales stacked flat
I prefer to stack bales flat. They feel very stable that way and the strings are nicely out of the way in the centre of the wall. They don't get cut accidentally and they are not in the way when shaping around doors or windows.

A bale laid "flat" – the strings are in the centre of the wall

Bales stacked on edge
When building using the framed method, some builders prefer to stack their bales on edge. The walls are narrower that way and some research has shown that heat transfer is less because of the orientation of the straw. For more on this see my MSc AEES thesis at http://www.homegrownhome.co.uk/homegrownhomeresearch.html

Photo courtesy of Jim Carfrae – straw bales stacked on edge at his straw bale home, Totnes, Devon – the strings are visible inside and out

A Dutch straw bale builder, Tom Rijven, places the bales on edge between narrow timber frames then cuts the string off so that the tension in the bales is released to push against each other and the timber.

Bales in floors and ceilings
The *best* performing straw bale wall has bales fitting together perfectly, sufficiently compressed to maximise its thermal properties and rendered both sides with lime or clay. This perfect scenario is more difficult to achieve in a floor or ceiling but then full fill, air tightness and minimal thermal bridging is difficult to achieve with most conventional materials and methods. Straw bales will probably be cheaper than any form of insulation but there may be additional structural costs because of the added weight.

Care is needed with straw bale insulation to floors – they must be protected from moisture from the ground and from the building (from leaking pipes or appliances for example).

Werner Schmidt, a Swiss Architect, uses straw successfully in the whole building envelope. www.atelierwernerschmidt.ch Architects Karen Allmer and Florian Macke successfully used straw bales in the roof of their new home in central Vienna. www.allmermacke.at

3.3 Foundations
A straw bale wall can be built off most types of foundation, bearing in mind the following

- protect the bales from moisture in the ground (elevating them off the ground is the simplest way)
- protect the bales from rain splashing on the ground – it can splash up over 400mm in a heavy downpour (common techniques include the use porches, rain screens or starting the first course of bales 450mm above ground level)
- provide drainage directly below the bales so that any moisture that does enter can safely leave (for example by placing bales on a layer of Lecca or granulated cork in a building requiring insulation)
- if the location is liable to flood, consider using pier foundations to raise the bales above the potential flood level

Decisions are made according to cost, local conditions, availability, suitability and longevity of materials, building control and structural engineer demands. Options include concrete or limecrete with brick and/or block stem walls, stone, recycled tyres or piers of timber, concrete, brick or steel. In all cases it is a good idea to provide a timber ladder frame on which to secure the first course of bales.

3.4 Wall finishes
Without *any* doubt – the best straw bale walls are plastered inside and out with a clay or lime based plaster – with the plaster being worked directly into the bales to form a composite structure. The plaster adds further strength to the bales, it makes the walls airtight and protects the straw from fire and vermin. It also improves

thermal performance by minimising heat loss by convection and it acts as a temperature and humidity regulator.

On elevations exposed to driving rain or conversely, elevations so sheltered that drying out is hindered, it is advisable to add a ventilated rain screen or a porch to keep the straw bale walls dry. The walls beneath the rain screen should still have at least 2 coats of plaster for the reasons discussed above.

Larch boards forming a ventilated rain screen over clay plastered straw bales at The Straw Bale Cottage

Clay and lime are the plasters of choice because they are “breathable” – water vapour can pass through, allowing the straw to dry. A cement render would trap moisture because it is not “breathable”.

Lime is best used externally because it is more weather resistant – unless clay is used behind a rain screen as in the photograph above. Lime can be used internally too but clay is a much more pleasant material to use, much more abundant and embodying much less energy. Lime and clay rarely work well together as they have different moisture characteristics - one is likely to delaminate from the other eventually. More information about clay and lime plasters and their application can be found at http://www.homegrownhome.co.uk/homegrownhomecottage.html

Mesh (plastic or wire) reinforcement within plasters is common in earthquake zones but is not necessary in most UK conditions.

It is labour intensive to get the first coat of plaster worked into the straw bale – even if the first coat is applied with a plaster gun, it should still be further worked into the bales as it is unlikely to have penetrated the compressed bales very far. It is well worth the effort for the performance reasons outlined earlier.

Applying the first coat of lime render by hand at The Straw Bale Cabin

Personally, I love putting my energy into a straw bale wall in this way but most building contractors do not and many clients think that it is not worth the added expense. For this reason it is common to find bales clad with a variety of boards – OSB, wood fibreboard or plasterboard. Quicker, cheaper and easier but definitely falling short of the ultimate thermal performance and risking fire and vermin spreading behind the boards.

The majority of straw bale owners prefer to accentuate their straw bale walls with curvaceous plastering – rounded window reveals and corners and decorative features in or on the plaster are commonplace. However, it is possible to have perfectly clean, straight edges if this look is preferred.

3.5 Roof design

As the over riding requirement is to protect the straw bale walls from as much rain as possible, the main requirement of a straw bale building is a roof overhang of at least 500mm. Where this is not possible, a rain screen could be used instead.

A hipped roof theoretically spreads the roof weight more evenly around the straw bale walls but it is a very leaky kind of roof until it is completed. A simple mono or duo pitched roof is the quickest to secure against the weather and easiest to maintain in the long run. It also needs less guttering.

Renewable roofing materials include oak or cedar shingles and thatch. As they are constantly exposed to wind, rain, sun, snow and wide temperature variations, the life expectancy of these materials on a roof is little over 20 years. They are wonderful natural materials that compliment renewable straw bale walls but there is nothing wrong with a roof of locally made clay tiles that will protect the walls for at least 60 years.

3.6 Building regulations

Currently there are no special rules for straw bale buildings in the UK. The building inspector applies the same rules as he would to any other method of construction. He will probably look very carefully at the structural engineers calculations and will ask about fire resistance.

A straw bale wall far exceeds the thermal performance expected under UK building regulations.

It is advisable to use an independent building inspector. There are helpful local authority ones but it is a lottery – for the same price you can appoint an independent who you can be sure will be helpful and proactive rather than a hindrance!

Other countries have much tougher building regulations. US building codes are very prescriptive for straw bale and lag behind recent developments such as in natural, breathable renders. David Eisenberg and Martin Hammer have been working long and hard in the States to improve their straw bale building codes. www.dcat.net

In Germany load bearing straw bale buildings are not permitted at all– their buildings must be over engineered to the point where only one in a million could fail. This makes them very expensive and resource hungry.

The eminent German straw bale expert, Professor Minke is well known, however for building straw bale vaults in other countries. You can see his latest project in Slovakia at www.minke-strawbaledome.blogsopt.com

3.7 Other ways to use straw in construction

Cob – predominantly clay with some added straw used to form wide, thermally massive walls.

Light straw – predominantly straw with a clay added to "glue" it together. It is shaped into walls with formwork. www.econesthomes.com

Chopped in plaster – chopped straw added to clay or lime plaster can be used to thickly plaster walls in existing properties – a good way to add insulation and improve air tightness.

Straw boards – the Stramit Technology Group us
e wheat straw in a patented process of heat and pressure to fuse straw with its internal resins to form strong boards 35mm to 60mm thick. A new factory is planned for the UK in the near future.
www.stramit.co.uk

Stakbloks – compressed interlocking blocks of rice straw made in the US
www.oryzatech.com

4. Why we should build with straw

4.1 Exceptional thermal performance

Super-insulated straw bale walls help to keep a building warm in winter and cool in summer – saving energy and keeping fuel bills low.

The thermal conductivity of wheat straw is in the region of 0.060 W/mK. The table below shows how this information is used to calculate a u-value of 0.123 W/m^2K for the Straw Bale Cabin's walls where the bales were 475mm thick.

Wall assembly	**Thickness m**	**Conductivity (λ) W/mK**	**Resistance m^2K/W**
Internal surface resistance	-	-	0.130
Earth plaster	0.025	0.800	0.031
Straw bale	0.475	0.060	7.917
Lime render	0.025	0.870	0.029
External surface resistance	-	-	0.040
Total thickness of wall	0.525		
Total resistance of wall			8.147
U-value ($u=1/R_t$)	**0.123**	**W/m^2K**	

To put this result into perspective, UK building regulations require a u-value of 0.3 W/m^2K for extensions, the AECB silver standard requires a u-value of 0.25 W/m^2K and gold standard requires 0.15 W/m^2K. The Cabin walls are easily good enough to meet even the best of these standards. The bales used for the walls of the Straw Bale Cottage are even wider at 500mm giving a u-value of 0.117 W/m^2K.

Insulation, however, is only one of several factors affecting the thermal performance of a wall system. The way building standards currently assess only heat loss by conduction is seriously flawed. To include all other parameters would be even more advantageous to straw and other natural building methods.

There are five energy saving advantages of a rendered straw bale wall that help to keep a building warm in winter and cool in summer;

1. Straw is an excellent insulating material – heat does not travel through it very quickly
2. Straw walls are solid – there are no gaps in the insulation contributing to unseen heat loss (which is commonplace in standard construction methods)
3. As even a small bale is 450 – 500mm wide, there is a significant time lag for heat transfer due to the thickness of the bale
4. The lime and clay plasters combined with the bales help to make the building airtight – preventing unwanted heat loss through the cracks and gaps that are commonplace in conventional constructions
5. Clay plaster on the interior acts as a temperature and humidity regulator to maintain a constant internal environment

There is more information about this in my MSc AEES thesis at
http://www.homegrownhome.co.uk/homegrownhomeresearch.html

4.2 Cost effective

Straw, being an agricultural rather than a manufactured product, is a very cheap source of insulation even though straw bale builders should be prepared to pay a little more than agricultural prices to ensure good quality building bales.

However, the cost of the walls is only a small part of the total build cost. Saving a few thousand pounds on the wall can be insignificant on a large project and as other natural materials such as sheep's wool, wood fibre or natural finishes can be much more expensive then conventional, mass-produced building materials – savings on the wall are soon gobbled up elsewhere!

Savings can be made if you are able to use your own labour to build and plaster the straw walls but the biggest savings will be the significant reduction in heating and cooling costs over the entire life of the building.

4.3 Renewable

The use of non-renewable resources for construction in the UK is *three times* the sustainable rate. In other words we need three planets the size of the Earth to continue to provide the construction materials we are currently using.

More renewable materials must be brought into the equation – especially materials such as straw or hemp that can be grown *every* year.

4.4 Carbon storage

Straw bale walls act as a carbon sink. Cereal crops photosynthesise as they grow, taking in carbon dioxide from the atmosphere. Every 10kg of straw absorbs nearly 15kg of carbon dioxide, sequestering it in the walls for the lifetime of the building (1.47kg CO^2 is stored per kg of straw (400kg C in a tonne of straw, multiplied by 3.67)).

Assuming 4 tonnes of straw per hectare, 5,880 kg CO^2 would be stored if the straw from one hectare was used in construction or nearly 12 million tonnes CO^2 if *all* straw could be sequestered in this way. A much better carbon sink than piping CO^2 under the sea!

Trees can capture 15t CO^2 per hectare per year - nearly 3 times the amount captured in straw and so timber building products would seem a better carbon store. However, forest cover in the UK is one of the lowest percentages in Europe at 12% (3 million hectares) and as construction grade timber can take 50 years to grow it will take too long to produce enough home grown material (not that we shouldn't be planting more). Straw is produced with the cereal crop every year.

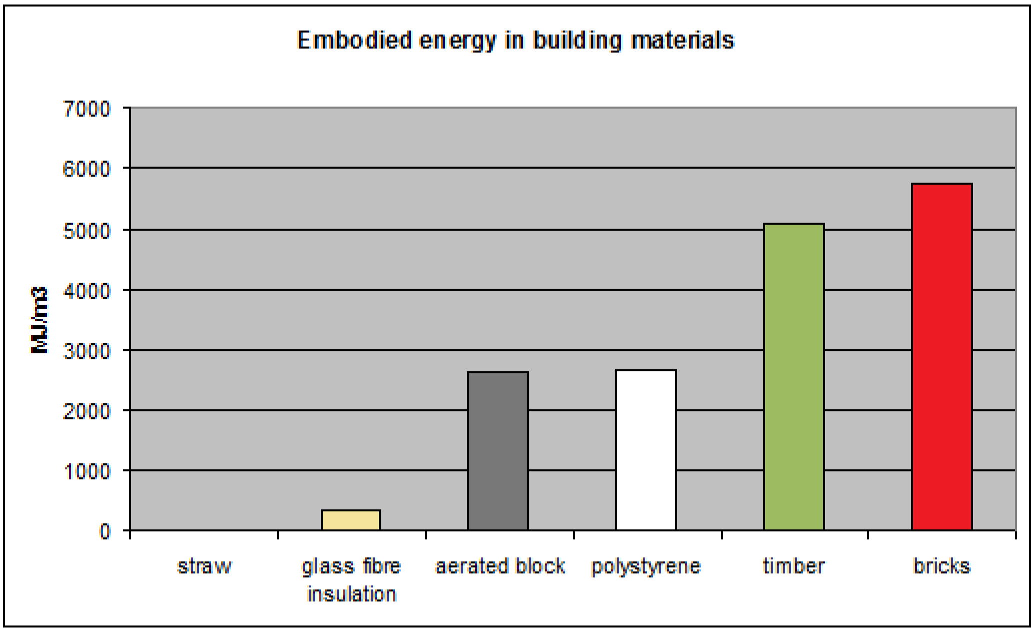
4.5 Low embodied energy

The embodied energy of a material is typically the total energy required to produce it. That could include the energy needed for growing, recycling, extracting, processing and transport for example. About 10% of national energy consumption is used in the production and transport of construction products and materials.

Most conventional building materials such as bricks or cement have high-embodied energy because a great deal of energy is required for extraction from the ground and processing at very high temperatures. As only a small percentage of construction grade timber is grown in the UK, imported timber embodies the energy needed for transport over long distances.

Straw, on the other hand, has low embodied energy. A figure of 0.24 MJ/kg is obtained when the energy used to grow the crop is assigned to the grain (this being the primary reason for growing the crop). The graph below illustrates the embodied energy calculations from the University of Bath. It highlights how the energy involved in making straw bales barely registers on the scale when compared to the energy needed to make other building materials.

The figure for recycled steel is not included in the graph below because it is 13 times the figure for bricks and including it would make the graph too big for the page!



Graph showing the energy embodied in building materials, using figures originating from the Sustainable Energy Research Team (SERT) at the University of Bath and accessed on 24/11/2010 at http://www.greenspec.co.uk/embodied-energy.php

There are, as always with figures, different ways to calculate them. A Swiss company (www.ecoinvent.ch) working in Life Cycle Analysis uses more of a mass allocation between straw and grain (rather than the economic allocation above) and includes capital inputs such as the impact of making the tractor. The result of their analysis is

0.4 – 1 MJ/kg baled and stored with the lower figure being for organic straw, which is grown without manufactured nutrients (from a personal communication with Andrew Norton, director, Renuables www.renuables.co.uk). Although the Swiss figure is up to 4 times more than the figure used in the above graph, straw would still barely feature on the scale – and the figures for the other materials would also rise under the revised methodology.

4.6 Very low carbon emissions
The low energy requirement for straw bale production as described above, means that there are very low carbon emissions at the construction stage. Compared to the construction of the average UK home where approximately 50 tonnes of carbon dioxide is emitted, the construction of a house with local and/or renewable and recycled materials would emit only a fraction of that.

The exceedingly good thermal performance described above ensures very low carbon emissions from heating or cooling over the life of the building (which can be a very long time).

4.7 Locally available
A cereal crop, and therefore straw, can probably be grown within one hour of even the most inaccessible, mainly upland, places in the UK. Even where building materials are made in the UK rather than being imported, the manufacturing sites are unlikely to be on the doorstep.

As with any material, the closer your source of bales the less energy required to transport them.

4.8 Reduced material requirement
A straw bale is the building block, the insulation and the surface for plaster. In addition, a load bearing design reduces the timber requirement. Currently, 50% of all raw materials are used in construction.

4.9 Excellent sound insulation
Straw bale buildings are unbelievably quiet. The thick walls deaden sound.

4.10 Non-toxic
Straw bales are non-toxic. There is no off gassing from nasty chemicals as there can be with many man made insulation products. It is best to use clean and dry straw to minimise dust and mould exposure during the build. Once encapsulated in the wall there is rarely problems when there is good design in the first place, considerate execution and proper maintenance there after.

4.11 No waste
There is no waste in the construction phase as all loose straw or spare part bales can be either composted or used for animal bedding. All it takes is a little discipline on site to tidy the straw up into spare sacks at regular intervals and to ensure that scraps of baler twine are separately stored.

A straw bale or other building made with natural materials can last a very long time because they are carefully detailed to protect them from their main enemy – rain! But when a natural building has served its useful purpose, it can be exposed to the elements, allowing it to biodegrade. No need for landfill!

4.12 Adaptable, creative and user friendly

Straw bales are in effect large building blocks but they can easily be cut and shaped to form a desired shape. Their natural undulations can be accentuated or they can be used to create very straight walls depending on preference.
Small straw bales are light enough to carry, easy to shape and quick to build.

5. Examples of straw bale buildings

Straw bale buildings range from simple to extravagant, small to enormous, cheap to expensive. They can be for domestic, commercial or community use. They can be self-built or professionally built – on site or off. Straw bales can be used for new builds, renovations or extensions.

Here a variety;

Steve James, self built £4,000 straw bale home near Dumfries, Scotland

http://www.independent.co.uk/life-style/house-and-home/property/how-i-built-my-house-for-1634000-784278.html

Semi detached straw bale council houses, North Kesteven, completed in 2010 under the direction on Amazon Nails (under £100,000 per house)

Nigel and Julie Wookey's four bedroomed home, Wiltshire (undisclosed sum)

http://www.dailymail.co.uk/news/article-1328455/Ill-huff-Ill-puff-Britains-biggest-straw-house-nears-completion.html

Straw bale extension to a brick house, Ontario, Canada by Evolve Builders

For straw bale extension in Norfolk, England see
http://www.mattmuldoon.blogspot.com/

Straw bale classroom, East Yorkshire – completed in 2011 by Sam Atkinson LLP

Straw bale school extension, Liverpool – completed 2009 under direction from Sam Atkinson

Pre fabricated straw bale panels - depot for York City council by Modcell

http://www.modcell.com/projects/york-ecodepot/

6. Websites

www.homegrownhome.co.uk
The authors website containing her personal experience of building with straw and hosting her own and other research papers.

www.strawbale-building.co.uk
Chugs site with lots of photos of straw bale projects and links

www.strawbalehouse.co.uk
Brian Waite's innovative straw bale house in Cumbria

www.designedtobreathe.com
Rachel and Andrews great blog as they build their straw bale home near Cambridge

www.simondale.net
Simons self built, very affordable, straw bale low impact woodland home in Wales – great photos and information

www.amazonails.org.uk
Lots of photos of straw bale projects, books and links

www.strawbale-net.eu
The European straw bale networking site with straw bale forum.

www.ilbi.org
The International Living Building Institute – the most advanced green rating system in the world!

www.thelaststraw.org
The home of the international straw bale journal

www.ecobuildnetwork.org
Source of many straw bale research papers

www.strawbale.com
Andrew Morrison's website – much practical straw bale building advice (with a US bias)

www.grossbotte.com
Website with great photos and links with buildings built with big straw bales

www.ozartur.sk
Slovak national straw bale website with lots of straw bale pictures – but not on the English pages – go to "eko info" then "slama v sk"

www.baubiologie.at

Austrian straw bale site

www.fasba.de
German straw bale site

www.la-maison-en-paille.com
French straw bale site

www.strawbale.com.au
Australian straw bale website

www.naturalhomes.org
Mapping natural buildings around the world

7. Reading list

The Last Straw
Regular US journal about straw bale building. Available online. Contributors from all over the globe. Excellent resource. Highly recommended. www.thelaststraw.org

***Design of Straw Bale Buildings, The State of the Art*.** 2nd edition 2006.
By Bruce King. Published by Green Building Press.
ISBN 978-0-9764911-1-8
An excellent American book bringing together research by leading straw bale experts from around the world. It is a well-structured and comprehensive technical guide and an absolute must for the serious straw bale builder. Highly recommended.

***Building with Straw Bales: A practical guide for the UK and Ireland*.**
By Barbara Jones. 2nd edition. Published by Green Books. 2009
ISBN 978 – 1900 322515
The best UK straw bale book, recently updated. Highly recommended.

The Beauty of Straw Bale Homes.
By Athena and Bill Steen. Published by Chelsea Green Publishing Company.
ISBN 1-890132-77-2
The photographs in this book are truly inspirational. Highly recommended.

Small Straw Bale: Natural homes, projects and designs
By Athena and Bill Steen and Wayne Bingham. Published by Gibbs Smith. April 2005.
ISBN 1-58685-515-8
More inspiring colour photographs from the same authors. Small is beautiful! Highly recommended.

Building with Straw. Design and Technology of a Sustainable Architecture. 2004.

By Gernot Minke and Friedemann Mahlke. Published by Birkhauser.
ISBN 3-7643-7171-4
Some good technical information and photographs with more of a European bias. There is a more up to date version, published only in German.

Serious Straw Bale – A Home Construction guide for all climates
By Paul Lacinski and Michel Bergeron. Published by Chelsea Green Publishing Company 2000
ISBN 1-890132-64-0

Build it with Bales – A Step by Step Guide to Straw Bale Construction
Matts Myhrman and S O Macdonald. Published by Out on Bale 1999
ISBN 0-9642821-1-9

Straw Bale Details
By Chris Magwood and Chris Walker. Published by New Society Publishers
ISBN 0-86571-476-2

Natural Building: A guide to Materials and Techniques
By Tom Woolley. Published by The Crowood Press Ltd. 2006
ISBN 1-86126-841-6
A balanced discussion of straw, earth, timber and hemp building in the UK. Also includes chapters on green roofs, natural insulation and paints. Interesting photographs and drawings. Highly recommended.

Lime in Building – a Practical Guide
By Jane Schofield www.blackdogpress.co.uk
ISBN 0 9524341 2 1
Practical advice on preparing and using lime

Using Natural Finishes
A step by step guise to using lime & earth-based plasters, renders and paints
By Adam Weismann & Katy Bryce. Published by Green Books in 2008
ISBN 978 1 900322 16 4